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THE IMF Bz AND SOLAR WIND SPEED DEPENDENCE FOR PRECIPITATING ION HEMISPHERIC ENERGY FLUX

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ABSTRACT

A new statistical study of the total power input to high latitude regions from precipitating ions, making primary data sorts by the IMF Bz and solar wind speed, shows that a) the minimum power input occurs for low, positive values of Bz and low values of Vsw, b) the power input increases proportionately more with increasing Vsw than with increasing Bz negative.

INTRODUCTION

One measure of the effectiveness of energy transfer from the solar wind to the magnetosphere is the total energy flux of particles precipitating into the high latitude regions. Previous statistical studies have determined the power input of precipitating electrons as a function of the geomagnetic activity index Kp /1,2,3,4/ and for the interplanetary magnetic field (IMF) Bz component either positive or negative /4/. Power input from precipitating ions as a function of Kp was determined by Hardy et al. /5/. These studies show that the total precipitating electron energy flux is directly proportional to KP, and that electrons contribute about seven times the energy flux of ions. Foster showed that more electron energy flux flows into the auroral regions during periods of Bz south than for Bz north /4/.

Efforts to quantify the solar wind-magnetosphere electrical coupling strength, by relating the cross-polar-cap potential difference to combinations of the solar wind speed and the direction of the IMF have been reviewed by Reiff and Luhmann /6/. A direct dependence of the potential difference has been shown for KP, solar wind speed, and magnitude of the southward component of the IMF. However, the coupling is not so clearly defined for times during which Bz is northward.

Here we present results showing the variation of ion energy flux input to high latitudes as a function of the IMF Bz and the solar wind speed, Vsw. By making separations of the precipitating ion data for strong and weak Bz north and south, as well as a low and high Vsw, we have found that the minimum power input occurs for weak Bz north and low Vsw, and that the dependence on Vsw is strong.

INSTRUMENTATION, DATA COVERAGE AND STATISTICAL PROCEDURES

The data used in this study were taken onboard two United States Defense Meteorological Satellite Program satellites, DMSP/F6 and DMSP/F7. The satellites are in sun-synchronous, circular, polar orbits at 840 km altitude, and are three-axis stabilized. DMSP/F6 orbits lie in the 0640-1840 meridian plane, and DMSP/F7 in the 1030-2230 meridian plane. On each satellite, electrostatic analyzers of identical design measure electrons and ions in the energy range from 30 eV to 30 keV in twenty logarithmically spaced intervals /7/. For each species a complete spectrum is returned each second. The detectors' apertures are fixed with respect to the satellite, pointing upward. At high latitudes they measure precipitating particles.

Due to the offset between geographic and geomagnetic poles, the sun-synchronous satellites, each day, sweep out a wide swath of values in corrected geomagnetic latitude (MLAT) and magnetic local time (MLT). Thus, the combined satellite, combined hemispheric data coverage is nearly complete for this coordinate system in the auroral regions. There are minor data gaps in the postnoon and postmidnight local time sector for active periods when the auroral oval has expanded to low latitudes.

We use data collected for three years on the DMSP/F6 satellite and two years on the DMSP/F7 satellite (5 satellite-years of data) and spanning the time period January, 1983 to March, 1986, to create statistical maps of ion precipitation in MLAT-MLT coordinates. The spatial grid into which the data are binned has an MLAT resolution of 2 degrees for 50-60 and 80-90 degrees MLAT, and 1 degree for 60-80 degrees MLAT, and an MLT resolution of one half hour.

Additionally, the data are sorted by the IMF component, Bz, in solar magnetospheric coordinates, and the solar wind speed, Vsw. Each ion spectrum in the data base is associated with a one-hour averaged value of Bz and Vsw, taken from the listing provided by NSSDC, and offset by a one-hour time lag. There are 4 IMF Bz bins: Bz large and negative (-10 to -3 nT); Bz small and negative (-3 to 0 nT); Bz small and positive (0 to +3 nT) and Bz large and positive (+3 to +10 nT). The average Bz values for each bin are -4.6, -1.3, +1.3, and +4.6 nT, respectively. There are 2 Vsw bins: low (from 200 to 400 km/s) and high (from 400 to 800 km/s), with average Vsw values of 364 and 518 km/s, respectively. Ultimately, 17 million ion spectra are separated into the eight primary Bz-Vsw maps defined in MLAT-MLT coordinates. The statistics for the low Vsw cases range from .5 to 1.8 million spectra/-map, while the range for the high Vsw cases is from 1.4 to 4.9 million spectra/map.

For each MLAT-MLT bin an average ion spectrum is calculated. Data gaps in the spatial coverage are filled by interpolating between neighboring data points. Since a significant portion of the high energy tail of ion spectra in the evening diffuse auroral region lies beyond the 30 keV cutoff of our instrument we extrapolated the average spectra to 100 keV. This results in a correction of the hemispheric energy flux which is dependent on activity level and ranges from an increase of 14% for the quietest case (low Vsw, weak Bz north) to 75% for the most active case (high Vsw, strong Bz north). The same qualitative trend of energy flux versus Bz/Vsw occurs for both the unextrapolated and the extrapolated cases. However, we believe that the extrapolated values provide a necessary correction to the otherwise artificially depressed values due to the detectors' upper limit of 30 keV. See Hardy et al. /5/ for details on data reduction techniques (cross satellite normalization, smoothing, and extrapolating).

For each spatial bin we calculate moments of the distribution function from the average spectrum, and, in particular, the energy flux. We then integrate over the full spatial map (i.e., above 50° MLAT), using the assumption that the distributions are isotropic, to obtain the total precipitating ion energy flux input for each of the eight average interplanetary conditions.

RESULTS AND DISCUSSION

The total hemispheric precipitating ion energy flux, in gigawatts, is tabulated in Table 1 and plotted in Figure 1b for the eight Bz-Vsw conditions.

TABLE 1 Hemispheric Energy Flux (G Watts)

Vsw / Bz	-4.6 nT	-1.3 nT	+1.3 nT	+4.6 nT
364 km/s	4.67 (3.02)	2.02 (1.39)	1.36 (1.19)	1.85 (1.56)
518 km/s	5.74 (3.27)	2.96 (1.87)	2.27 (1.53)	2.91 (2.14)

Note: Energy flux values from unextrapolated spectra are in parentheses.

For a constant value of Vsw, the hemispheric energy flux maximizes for strong Bz south, minimizes for weak Bz north, and has nearly equal intermediate values for weak Bz south and strong Bz north. The variation in energy flux for each Bz interval, due to the Vsw difference alone, is a constant 1 GW (for extrapolated values). This offset is significant both because of its relatively large magnitude and because of its independence of Bz. If we define the ground state of the magnetosphere as one in which the precipitating particle energy flux is minimized, then the ground state occurs during periods of weak Bz north and low Vsw. It is not the limit of extrapolating low solar wind velocity states to higher and higher positive values of Bz.

In Figures 1a and 1b we summarize the results of the major studies of precipitating particle energy flux input using low altitude satellite data.

Figure 1a gives the total precipitating energy flux into the auroral zone as a function of Kp for electrons (filled symbols) and ions (open symbols). The agreement between the various electron studies is excellent. For both electrons and ions the log of the energy input increases in a linear fashion with increasing KP for KP greater than one. The minimum value is ~5 GW for electrons and ~.7 GW for ions. Both values are somewhat depressed below a projected linear value. For this and other values of KP, the electrons contribute between 6 - 8 times the energy flux of ions.

Figure 1b shows the results of the ion study discussed above, and those of Foster /4/ for which electron data were separated into two Bz bins, > +3 nT and < -3 nT. For comparison with Foster, the ion energy flux for the high and low Vsw cases are averaged for the corresponding values of Bz. The electron energy flux input is about 6 times that for the ions, in agreement with the Kp studies. Assuming that the same scaling of energy flux between electrons and ions holds for all values of Bz, we infer that as a function of Bz the minimum electron power input should be about 11 GW and would also occur under weakly positive Bz conditions.

Comparing the minimum energy input values as a function of KP and as a function of Bz-Vsw, we note that the energy flux input for KP = 0, 0+ is lower than that for low Vsw and weakly positive Bz. Possible explanations for this include: 1) the corresponding Bz/Vsw bin was too broad ; 2) conditions additional to the instantaneous value of the solar wind speed and the z-component of the IMF are required to specify the condition of weakest precipitating particle energy flux input.

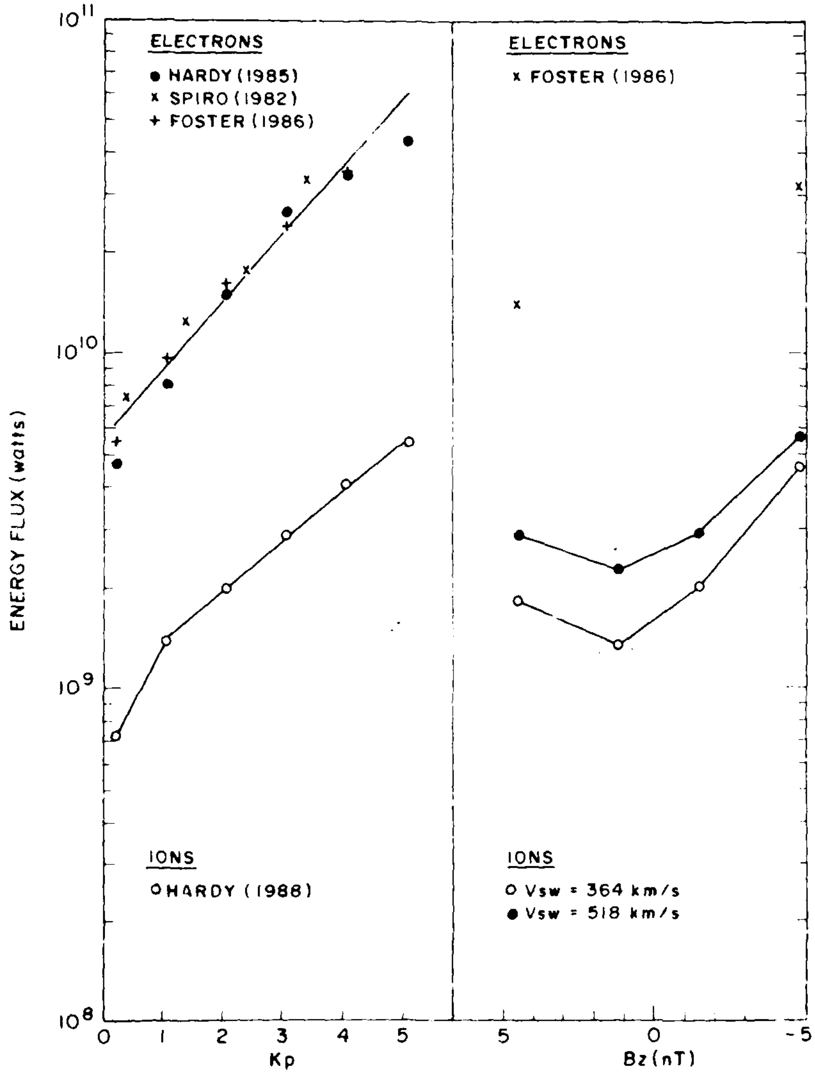

Fig. 1. Precipitating electron and ion hemispheric energy flux as a function of (a) Kp and (b) IMF Bz.

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